Effects of changing clinical practice on costs and outcomes of percutaneous coronary intervention between 1998 and 2002

INTERVENTIONAL CARDIOLOGY

Effects of changing clinical practice on costs and outcomes of percutaneous coronary intervention between 1998 and 2002

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Aim: To assess the effect of changing clinical practice on the costs and outcomes of percutaneous coronary intervention (PCI) between 1998 and 2002.
Setting: Two tertiary interventional centres.
Patients: Consecutive patients undergoing PCI over a 12-month period between 1998 and 2002.
Design: Comparative observational study of costs and 12-month clinical outcomes of consecutive PCI procedures in 1998 (n = 1047) and 2002 (n = 1346). Clinical data were recorded in the Scottish PCI register. Repeat PCI, coronary artery bypass graft and mortality were obtained by record linkage. Costs of equipment were calculated using a computerised bar-code system and standard National Health Service reference costs.
Results: Between 1998 and 2002, the use of bare metal stents increased from 44% to 81%, and the use of glycoprotein IIB/IIIA inhibitors increased from 0% to 14% of cases. During this time, a significant reduction was observed in repeat target-vessel PCI (from 8.4% to 5.1%, p = 0.001), any repeat PCI (from 11.7% to 9.2%, p = 0.05) and any repeat revascularisation (from 15.1% to 11.3%, p = 0.009) within 12 months. Significantly higher cost per case in 2002 compared with 1998 (mean (standard deviation) £2311 (1158) *v* £1785 (907), p<0.001) was mainly due to increased contribution from bed-day costs in 2002 (45.0% (16.3%) *v* 26.2% (12.6%), p = 0.01) associated with non-elective cases spending significantly longer in hospital (6.22 (4.3) *v* 4.6 (4.3) days, p = 0.01).
Conclusions: Greater use of stents and glycoprotein IIb/IIIa inhibitors between 1998 and 2002 has been accompanied by a marked reduction in the need for repeat revascularisation. Longer duration of hospital stay for non-elective cases is mainly responsible for increasing costs. Strategies to reduce the length of stay could considerably reduce the costs of PCI.

Percutaneous coronary intervention (PCI) is now the most commonly used form of coronary revascularisation in the UK.[1 2] Technological advances in equipment and adjuvant drug treatments over the past 15 years, including stents, glycoprotein IIb/IIIa inhibitors and clopidogrel, have improved clinical outcomes,[3–6] but potentially added to procedure-related costs. The cost effectiveness of these advances has been examined in the context of randomised trials, and in each case has suggested that the additional costs are recouped by reduced need for readmission to hospital, reduced need for repeat revascularisation procedures, or both.[7–10]

When estimating costs and cost effectiveness of PCI in clinical practice, there are several important factors to consider. Firstly, although new technologies, such as stents, are initially expensive, the cost has fallen with time as their use increases and competition among manufacturers has increased. Secondly, stents are only one of the main cost drivers of PCI. Angioplasty balloons, bed-days and adjuvant drug treatment also contribute appreciably to procedural costs.[11] Thirdly, it is not known whether the net effect of multiple new interventions is achieved in ''real-world'' clinical practice. ''Real-world'' patients tend to be older, have more comorbidity and are generally more heterogeneous than those in randomised trials. Therefore, there is a need to assess the costs and outcomes of PCI with time and with changing technologies in the clinical setting to which they are applied. This is increasingly important as new systems of financial remuneration are introduced in the UK[12] and elsewhere in the world.[13 14]

In this study, we have compared detailed procedural costs of PCI in unselected consecutive cases over a 12-month period in 1998 and 2002 at two interventional centres when there were considerable changes in clinical practice.

METHODS

Patient recruitment

In all, 1047 and 1346 consecutive patients with a PCI procedure in the two centres between February 1997 and May 1998, and February 2001 and February 2002, respectively, were included in the analysis. Data were recorded prospectively at each centre in an Access database as part of the Scottish PCI register, including clinical status of the procedure (non-elective or elective), cardiovascular risk factors, severity of coronary disease, left ventricular function, vessel diameter and number of bare metal stents (BMS) deployed. Ethical approval for the study was obtained from the appropriate research ethics committees at both the centres involved.

Procedural costs

The first stage was to explore which elements of the cost of a PCI were the most important so that these could be the focus of further data collection. The use of BMS, balloons, wires, guides, standard equipment, standard drugs, contrast and staff costs were assessed in 100 consecutive cases in the year 2000. For these cases, the items that acted as the main cost drivers were found to be BMS, balloons and bed-days; the remaining items made up only 10–20% of the total costs and were combined as a fixed cost. Further data collection centred on these items, as well as glycoprotein IIb/IIIa inhibitors, which came into use after this time. These 100 cases were found to be representative of the larger cohort studied for urgency, age, disease severity and number of vessels treated.

Abbreviations: BMS, bare metal stents; CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention

For each of the 1047 PCI procedures in 1998, cost per procedure was calculated by using fixed costs (as defined above) added to the three main cost drivers (bed-days, balloons and BMS) for each case (appendix). Data on use of balloons and BMS for each procedure were taken from the PCI register, and time in hospital was taken from the individual patient's data recorded in the Scottish Morbidity Record 1 system, multiplied by the reference cost for one day's stay in a standard medical ward (Scottish Health Service Costs.[15]

For the estimation of costs of PCI cases in 2002, detailed information was collected prospectively on all 1346 consecutive procedures and included the number of balloons, BMS, duration of hospital stay, guide wires, guide catheters, non-standard equipment and use of glycoprotein IIb/IIIa inhibitors for each PCI procedure. A fixed quantity for the remaining cost components (standard equipment, standard drugs and staff) was added to obtain the total cost of each procedure (appendix). Capital costs of equipment and buildings were not included in the calculations.

Outcomes of PCI

Outcome data were collected via linkage of records in the PCI register, with the Information and Statistics Division of the Common Services Agency using data on deaths from the Scottish Mortality Record 1 and General Registrar. Subsequent events recorded included repeat PCI (K49 and K50.1) and coronary artery bypass graft (CABG; K40–K46). Any PCI procedure in the same arterial territory as the index PCI was defined as a repeat target-vessel PCI. These data were obtained from the PCI register. Dates of admission and discharge were obtained from the Information and Statistics Division to allow estimation of costs related to duration of hospital stay. Adverse events in the cardiac laboratory included acute closure of a major coronary vessel resulting in myocardial infarction (creatine kinase twice the upper limit of normal), side branch occlusion (resulting in myocardial infarction), urgent CABG, cerebrovascular injury, haemorrhage requiring transfusion, and vascular access complications. The success of the procedure was defined by the operator at the end of each procedure.

Statistical methods

Data are presented as mean (standard deviation (SD)) and 95% confidence intervals for the mean. The χ^2 test was used to compare percentages between groups. Means between groups were compared using analysis of variance or the t test.

RESULTS

Patient characteristics

Compared with 1998, patients treated in 2002 (table 1) were older, had a higher body mass index, had more single vessel disease, had significantly lower angina scores and were less likely to have left ventricular dysfunction. There was a similar number of patients with diabetes and hypertension, a lower proportion of current smokers and a greater number with previous myocardial infarction in 2002. The proportion of cases defined as non-elective in 2002 was significantly greater than in 1998 (43% *v* 31%, $p<0.001$).

Procedure-related differences between 1998 and 2002

Between 1998 and 2002 the use of BMS and also the use of glycoprotein IIb/IIIa inhibitors increased significantly (table 1). The maximum diameter of the treated vessel was significantly smaller in 2002. There was a higher rate of operator-defined procedural success in 2002 and a small but significant increase in in-laboratory adverse event rates. Adverse events reported in 2002 were due to myocardial infarction (19), cerebrovascular injury (4), femoral access site complications, including haemorrhage (10), emergency CABG (1) and death (1). The length of stay reduced slightly for elective procedures and increased considerably for non-elective cases. The mean (SD) length of stay for patients with an adverse in-laboratory event in 2002 was slightly shorter, although non-significant, compared with patients with no adverse event (3.9 (3.8) *v* 4.5 (3.6), respectively, $p = 0.37$).

Costs

Overall, there was a 30% increase in the average cost of a PCI procedure between 1998 and 2002 (table 2); this is equivalent to an annual inflation rate in the cost of the procedure of just over 6% at a time when the rate for the rest of the UK economy was running at about a half of that level. This change was most marked in non-elective cases, where a 47% increase was observed, an inflation rate of almost 10%. The main contribution to the increase in costs was bed-days (duration of hospital stay), with other equipment costs (BMS and balloons) contributing proportionally less in 2002 than in 1998.

Clinical outcomes

Comparing outcomes in 1998 with 2002 (table 3), there was a significant reduction in repeat target-vessel PCI (from 8.4% to 5.1%, $p = 0.001$) and a significant reduction in repeat PCI to any vessel (from 11.7% to 9.2%, $p = 0.05$) in the 12 months after the index PCI. There was no significant difference in the number of patients undergoing CABG, but overall, the total number of repeat revascularisations was significantly reduced (from 15.1% to 11.3%, $p = 0.009$) within 12 months of the first PCI in 2002 compared with 1998.

DISCUSSION

In this study, we observed that, between 1998 and 2002, in unselected consecutive patients undergoing PCI, greater use of BMS and glycoprotein IIB/IIIA inhibitors was associated with a similar 1-year mortality and a reduced need for repeat revascularisation within 12 months. These changes occurred despite a more adverse risk profile of patients treated in 2002, in relation to age, smaller vessel diameter, more previous myocardial infarction and a greater number of non-elective cases. Over the same time period, we observed a small increase in in-laboratory adverse event rates and a greater in-laboratory lesion success rate. These findings are in keeping with other data from PCI registry, suggesting that interventionists are increasingly treating older patients with more complex disease in smaller coronary arteries while improving lesion-related results, with no marked change in mortality.[16]

Between 1998 and 2002, we observed a 30% increase in the mean cost of a PCI procedure. The reasons for this increase in cost are complex and not simply due to greater use of BMS and adjuvant drugs. Stents contributed proportionally less to the mean cost of a PCI in 2002 compared with 1998. There was a marked difference in the change in costs between elective and non-elective procedures. The increase in mean cost for elective procedures was 10% over 5 years, which is broadly in line with inflation, whereas the greatest increase in costs was observed for non-elective procedures. This was largely due to a considerably longer average duration of stay for non-elective cases in 2002. The net change in cost of interventional procedures between 1998 and 2002 is therefore a complex sum of greater use of less expensive equipment, greater use of glycoprotein IIb/IIIa inhibitors offset by longer duration of hospital stay in an increasing proportion of non-elective procedures.

The question remains—does this change in clinical practice, resulting in greater cost, represent value for money? This is a difficult question to answer, but can be discussed by examining

Table 1 Characteristics of patients in 1998 and 2002

	1998		2002		
Factor	**n**	**Mean (SD) or %**	**n**	**Mean (SD) or %**	**p Value**
Age (years)	1047	59.4 (10.0)	1346	61.0 (10.2)	<0.001
Male (%)	1047	69	1299	67	0.39
BMI	988	27.2 (4.2)	704	28.3 (4.6)	<0.001
Number of diseased vessels (%)	1017		1263		
1		44		53	
2		32		30	
3		24		17	
Procedure status (%)	1043		1267		<0.001
Elective		69		57	
Non-elective		31		43	
Angina score (%)	1007		996		<0.001
0–1		3		29	
2–3		60		30	
4		37		40	
Left ventricular dysfunction (%)	808		1256		
Normal		59		77	<0.001
Mild		27		15	
Moderate		10		5	
Severe		3		3	
Smoking status (%)	1027		894		
Non-smokers		31		61	<0.001
Current smokers		23		9	
Ex smokers		46		30	
Diabetes (%)	1018	11	1131	11	0.8
Hypertension (%)	1021	35	994	33	0.46
Previous myocardial infarction (%)	1047	42	1157	37	0.013
Previous CABG (%)	1016	11	1224	11	0.64
Procedural success (%)	1047	92	1256	96	<0.001
In-laboratory adverse events (%)	1047	1.1	1346	2.7	<0.01
Any stents used (%)	1044	44	1346	81	<0.001
Stents used per procedure (mean)	1044	0.84 (1.20)	1346	1.16 (0.86)	<0.001
Vessel diameter (mm)	1031	3.17 (0.53)	1206	3.05 (0.48)	<0.001
Any GP IIb/IIa used	1047	0	1346	14	<0.001
Length of stay (days)	884	3.31(2.98)	1346	4.4(3.6)	<0.001
Elective	633	2.78(2.07)	727	2.72(2.1)	0.10
Non-elective	249	4.63(4.26)	540	6.22(4.3)	<0.001

BMI, body mass index; CABG, coronary artery bypass graft; GP, glycoprotein.

data from this study. For elective procedures, the additional cost per case was £174, which was close to that expected from inflation over a 4–5-year period and therefore represents an overall neutral effect on cost. Therefore, if we use the observed reduction in repeat revascularisation procedures of 3% for PCI and 1% for CABG (three PCI procedures and one CABG per 100 patients treated) in 2002 compared with 1998, this represents a net cost saving of approximately £12 000 per 100 elective cases treated. The same calculation for non-elective procedures produces a net increase in cost of approximately £40 000 per 100 cases treated in 2002 compared with 1998. It is clear therefore, that the cost effectiveness of BMS and glycoprotein IIb/IIIa inhibitors is being diluted in clinical practice by the effect of longer duration of hospital stay.

Increased length of stay may be partly related to increasing complexity of cases and is probably not related to an increased adverse event rate in 2002, as these patients had a similar length of stay to those patients with no adverse event. Longer

Table 2 Costs of percutaneous coronary intervention, 1998 *v* 2002

	1998		2002			
	n	**Mean (SD)**	**n**	**Mean (SD)**	**Change (%)**	**p Value**
Overall (cost, £)	1047	1785 (907)	1346	2311 (1158)	+30	<0.001
Elective (cost, £)	717	1694 (885)	727	1868 (782)	+10	<0.001
Non-elective (cost, £)	326	1989 (929)	540	2924 (1307)	+47	<0.001
Procedure cost (%)						
Stents (BMS; %)	1047	27.9 (32.8)	1346	19.9 (13.2)	−40	<0.001
Balloons (%)	1047	22.4 (20.3)	1346	6.4 (6.0)	−71	<0.001
Bed-days (%)	1047	26.2 (12.6)	1346	45.0 (16.3)	+72	<0.001
GP IIb/IIIa (%)	1047	0 (0)	1346	3.4 (8.7)		<0.000

BMS, bare metal stents; GP, glycoprotein.

Table 3 Clinical outcomes of PCI in 1998 and 2002

Outcome within 1 year of index PCI	1998 n	1998 n (%)	2002 n	2002 n (%)	p Value (χ^2)
Repeat target-vessel PCI	1047	101 (8.4)	1346	75 (5.1)	0.001
Repeat PCI (any vessel)	1047	122 (11.7)	1346	124 (9.2)	0.05
CABG	1036	40 (3.9)	1346	35 (2.6)	0.09
Any revascularisation	1036	156 (15.1)	1346	152 (11.3)	0.009
Death	1036	35 (3.4)	1346	38 (2.8)	0.46

CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention.

duration of stay is more likely to be due to organisational issues and the growing demand for inpatient angiography and intervention, resulting in delays in transfer of patients from district hospitals to the two interventional centres involved in this study.[17] It does suggest that a reduction in the length of hospital stay could markedly reduce costs of non-elective PCI. One possible mechanism that might improve this in our region would be the allocation of specific ''ring-fenced'' beds in interventional centres for patients requiring urgent angiography, allowing faster and efficient transfer of patients from district hospitals to interventional centres.[18]

Increased use of BMS from 44% in 1998 to 81% in 2002 observed in our registry would have been expected to result in a relative risk reduction in repeat revascularisation by approximately 25%,[4] which is very close to what we observed (15.1% to 11.3%). This suggests that the additional cost of BMS is being recouped in terms of reduced need for repeat procedures, but this is being diluted by the costs of additional bed-days. Reducing the length of hospital stay is a key part of the current strategy associated with payment by result.[19]

LIMITATIONS

There are limitations to this study that should be considered when interpreting the findings. The outcome data used in our analysis included hospital discharge coding in Scotland and hence, although the numbers are likely to be small, a patient admitted and treated elsewhere in the UK would not be included. The costs and outcomes presented do not constitute a cost-effectiveness analysis, but are simply an estimate of the procedure-related costs of PCI and the crude outcomes in terms of the need for repeat revascularisation. Some of the clinical data are missing, but most data relating to costs and outcomes were complete. Detailed information regarding the cause for longer hospital stays in non-elective patients are not available, and hence further studies are required to examine this.

CONCLUSIONS

Between 1998 and 2002, the costs of non-elective PCI procedures increased much more than inflation mainly due to an increase in the cost of bed-days associated with longer duration of hospital stay. During the same time period, the cost of elective PCI procedures increased in line with inflation. Although this may be partly due to increasing complexity of non-elective cases, clinical strategies that speed up transfer of patients and shorten hospital stay of non-elective PCI procedures could considerably improve its cost effectiveness.

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APPENDIX

Costs (£) used for calculation of procedure-related costs of percutaneous coronary intervention

Cost component	Cost (£) 1998	Cost (£) 2002
Standard equipment	102	105
Standard drugs	9	45
Radiographic contrast	35	38
Staff	112	115
Stents (BMS)	837	370
Bed-days	133	267
Balloons	289	137
Guide wires	50	50
Guide catheters	50	48
GP IIb/IIIa (abciximab)	NA	750
GP IIb/IIIa (small molecule)	NA	250

BMS, bare metal stents; GP, glycoprotein; NA, not available clinically in 1998.

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IMAGES IN CARDIOLOGY

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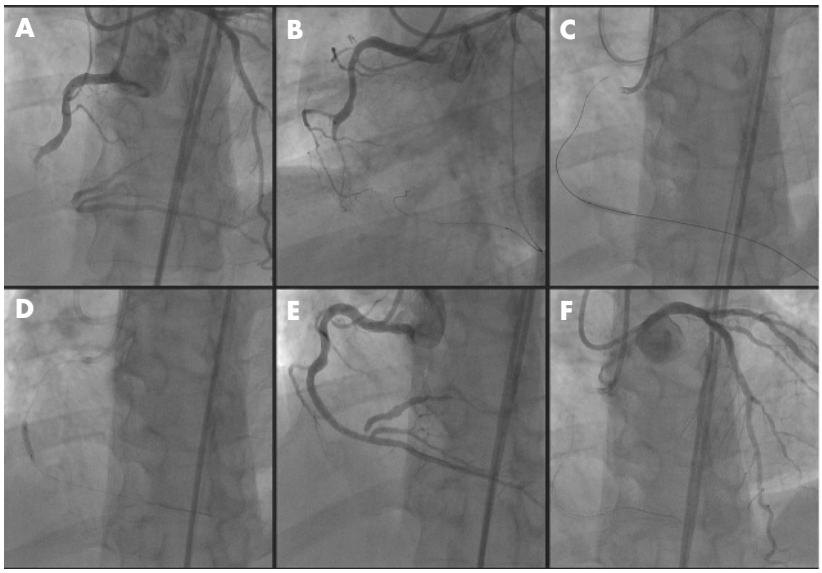
Retrograde coronary interventions of chronic total occlusions

A 43-year-old man presented with several months of effort angina. Angiography showed a totally occluded mid-portion obstruction of the right coronary artery (RCA) and very good collaterals from the left coronary artery, filling retrogradely the distal RCA (panel A). Multiple trials to cross the mid-RCA through an anterograde approach with various guide wires failed. Therefore, we finished the procedure and planned the retrograde RCA intervention after 2 days. Both coronary arteries were engaged by guiding catheters, and various guide wires were tried to pass the lesion through the collaterals retrogradely, but it was very difficult to pass the lesion (panel B). Finally, the guide wire (Conquest pro ASAHI INTECC, Osaka, Japan) passed the lesion with the support of a microcatheter (Renegade Boston Scientific, Natick, Massachusetts, USA). Then a 1.5–15 mm size percutaneous transluminal coronary angioplasty balloon (Ryujin, Terumo, Japan) was inserted through the collaterals via a retrograde guide wire and inflated to 10 atm (panel C). The second guide wire was introduced antegradely and easily passed the lesion. The lesion was successfully dilated (panel D) and two long Cypher stents (Cordis), 3.0–23 and 2.75–33 mm, were deployed over the antegrade wire. Panel E was the final angiograph. Finally, there were no visible collateral flows from the left coronary artery to d-RCA (panel F). The patient has remained asymptomatic for 3 months after angioplasty.



Successful intervention of chronic total occlusions has been reported to be associated with a favourable long-term outcome and may reduce the need for bypass surgery. If previous attempts to cross the totally occluded lesion from the anterograde approach fail, the retrograde approach from collaterals should be considered. This technique cannot be applied in all cases of chronic total occlusions, because it requires the presence of collaterals, but this method could be another choice for solving a problem.

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